

Chapter 3

Study Design and Methods

Study Design

This study evaluated the effectiveness of a wet abrasive blasting technology (Torbo®) combined with two inorganic-based stabilization technologies (Blastox® and PreTox 2000 Fast Dry) to remove lead-based paint from exterior substrates (brick and wood) and to generate a non-hazardous waste for disposal. Each technology combination (e.g., Torbo® with PreTox 2000 Fast Dry) was demonstrated on the two substrates (brick and wood) to yield two treatments. Each treatment was replicated three times to yield six experiments per technology combination. The study design is summarized in Table 1.

Table 1. Study Design for Lead-Based Paint Removal from Brick and Wood

Substrate	Number of Experiments		
	Torbo® with Blastox®	Torbo® with PreTox 2000	Total
Brick	3	3	6
Wood	3	3	6
Total	6	6	12

Brick -- A single building wall (approximately 28' H x 157' L) was used as the exterior painted brick substrate. This expanse of wall reportedly had the same construction and painting history. The lead loading (i.e., mass of lead in a given surface area on the substrate) on the brick ranged from 1.5 to 15.2 mg/cm² (average 6.9 mg/cm², std. dev. 3.2 mg/cm²) using a NITON Model 703-A X-ray fluorescence (XRF) spectrum analyzer (K & L Shell Combined). The masonry wall was divided into six areas that ranged from 556 to 756 ft² (average 627 ft²). The differences in surface area are due to the presence of varying numbers of windows on the wall; the respective areas were subtracted from each of the test areas. Each technology combination was assigned at random to the six test areas.

Wood -- Five buildings (two houses and three storage buildings with 4-inch poplar wood siding) were used as the exterior painted wood substrate. The buildings were located on the same property, had an identical architectural design, and reportedly had similar painting histories. The lead loading on the wood siding ranged from 13.1 to 51.9 mg/cm² (average 33.3 mg/cm², std. dev. = 10.1 mg/cm²) using a NITON Model 703-A XRF spectrum analyzer (K & L Shell Combined).

Two test areas were selected from one of the two houses, and one test area was selected from each of the remaining four buildings (i.e., one house and three storage sheds), yielding a total of six test areas. The six test areas ranged from 294 to 431 ft² (average 363 ft²). The technology combinations were randomly assigned to the test areas, but assignments were controlled to ensure that each technology combination was tested on a house.

Table 2 presents a summary of the sampling design for the environmental measurements. Table 3 presents a summary of the environmental sampling strategy.

Technologies Evaluated

Torbo® Wet Abrasive Blasting System

The Torbo® Wet Abrasive System is manufactured by Keizer Technologies of Americas, Inc. in Euless, Texas. The system uses conventional blasting abrasives mixed with water (80% abrasive to 20% water) in a pressure vessel. During this study, mineral slag was used to remove the paint from the brick and coal slag (Black Beauty®) was used to remove the paint from the wood.

The system combines the abrasive media and water to create a slurry-mixture that is fed to a blast nozzle much like a conventional blasting system. In concept, each particle of the abrasive is encased in a thin layer of water. It utilizes this coating to both reduce the heat generated by friction and form a cohesive bond for the dust created by the blasting process that reduces the fugitive particulate emissions.

Water pressure (175 psi) from a system piston pump forces the slurry-mixture from the vessel to a compressor-generated airstream (185 cfm minimum flow rate), where it is accelerated toward the blasting nozzle. The blast media consumption (0.01-0.23 cfm) and water consumption (0.03 - 0.42 gal/min) are both adjustable during operation. The paint coating is removed by the kinetic energy and mechanical abrasion of the blast media striking the surface. After the abrasive blasting of the brick or wood substrates was completed, power water rinsing (60 psi for wood and 95 psi for brick substrates) was performed on the surface to ensure that all of the abrasive-mixture was removed. The rinse option used approximately 5 gallons of water per minute. The water expended during the rinse cycle either evaporated or was absorbed by the abrasive on the polyethylene sheeting ground cover to form a sludge.

Table 2. Summary of Sampling Design for Environmental Measurements

Technology Combination	Substrate	Environmental Data to be Collected		
		Paint Removal Effectiveness	Work Area Contamination	Site Control
Torbo® with Blastox®	Exterior Wood Siding	<ul style="list-style-type: none"> ◦ XRF^a: pre/post removal ◦ ICP-AES^b: paint chip/bare substrate chip: pre/post removal ◦ Visual surface evaluations: post removal 	<ul style="list-style-type: none"> ◦ Air lead: during removal ◦ Air lead particle size: during removal ◦ Blasting debris: post removal 	<ul style="list-style-type: none"> ◦ Area air lead: during removal ◦ Soil lead: pre/post removal
	Exterior Brick	<ul style="list-style-type: none"> ◦ XRF: pre/post removal ◦ ICP-AES: paint chip/bare substrate chip: pre/post removal ◦ Visual surface evaluations: post removal 	<ul style="list-style-type: none"> ◦ Air lead: during removal ◦ Air lead particle size: during removal ◦ Blasting debris: post removal 	<ul style="list-style-type: none"> ◦ Area air lead: during removal ◦ Soil lead: pre/post removal
Torbo® with PreTox 2000 Fast Dry	Exterior Wood Siding	<ul style="list-style-type: none"> ◦ XRF: pre/post removal ◦ ICP-AES: paint chip/bare substrate chip: pre/post removal ◦ Visual surface evaluations: post removal 	<ul style="list-style-type: none"> ◦ Air lead: during removal ◦ Air lead particle size: during removal ◦ Blasting debris: post removal 	<ul style="list-style-type: none"> ◦ Area air lead: during removal ◦ Soil lead: pre/post removal
	Exterior Brick	<ul style="list-style-type: none"> ◦ XRF: pre/post removal ◦ ICP-AES: paint chip/bare substrate chip: pre/post removal ◦ Visual surface evaluations: post removal 	<ul style="list-style-type: none"> ◦ Air lead: during removal ◦ Air lead particle size: during removal ◦ Blasting debris: post removal 	<ul style="list-style-type: none"> ◦ Area air lead: during removal ◦ Soil lead: pre/post removal

^a Denotes X-ray fluorescence.

^b Denotes inductively-coupled plasma atomic emission spectroscopy.

Table 3. Environmental Sampling Strategy Matrix

Technology Combination	Substrate	Experiments per Substrate per Technology Combination	Sample Type	No. of Samples per Experiment	No. of Samples Collected per Substrate per Technology Combination ^a
Torbo® with Blastox®	Exterior Wood Siding or Exterior Brick	3	XRF	5/25 ^b	15/75
			Air Lead	1-2/2-6 ^c	3-6/6-18
			Air Lead Particle Size	1 ^d	1
			Soil	1 pair ^e	3 pair
			Paint Chip/Bare Substrate Chip ^f	3/5 ^f	9/15
			Blasting Debris	2	6
Torbo® with PreTox 2000 Fast Dry	Exterior Wood Siding or Exterior Brick	3	XRF	5/25 ^b	15/75
			Air Lead ^a	1-2/2-6 ^c	3-6/6-18
			Air Lead Particle Size ^b	1 ^d	1
			Soil	1 pair ^e	3 pair
			Paint Chip/Substrate Chip ^f	3/5 ^f	9/15
			Blasting Debris	2	6

^a Excludes QA/QC samples.

^b Includes five measurements before and 25 measurements after application of a paint removal technology.

^c One to two personal samples were collected on the technology operator and/or helper. Two to six area air samples were collected depending on the site configuration.

^d Personal sample was collected on the technology operator.

^e Pair refers to one 3-part composite sample before and one 3-part composite sample after application of a paint removal technology.

^f A 1¼" x 1¼" paint chip sample was collected before and a 1¼" x 1¼" bare substrate chip sample was collected after application of a technology.

Blastox®

Blastox® is manufactured by TDJ Group Inc. in Cary, Illinois. Blastox®, an abrasive additive, is a di- and tri-calcium silicate-based material similar in chemical composition to Type I cement. Typically, for lead-based paint removal, it is added at a 20-25 weight percent ratio to the non-recyclable blasting media such as mineral sand or coal slag. For this study, the supplier of the abrasive reportedly premixed the Blastox® additive at a 20 and 15 percent weight ratio to the abrasive (mineral sand or coal slag) for paint removal from the wood and brick substrates, respectively.

A U.S. Army Corps of Engineers study⁵ concluded that Blastox® stabilizes lead-containing paint blast media wastes (i.e., reduces the leachability of lead) by a series of simultaneous reactions that result in an encapsulated lead silicate compound, which is insoluble at all pH levels. The first reaction is a pH adjustment that simultaneously stabilizes the lead by adjusting the pH range (8.0-11.5) where there is limited leachability for lead. Secondly, the chemical form of the lead is changed from a lead oxide, carbonate, or hydroxide, to a lead silicate, which is insoluble. A U.S. EPA study⁶ concluded that Blastox® appears to stabilize the lead through an immobilization mechanism, rather than by chemical reaction of lead oxide, to form a lead silicate. Lastly, hydration reactions encapsulate the waste into a cementitious material, which limits the gravitational flow of water through the waste.

PreTox 2000 Fast Dry

PreTox 2000 Fast Dry (hereafter referred to as PreTox 2000) is manufactured by NexTec, Inc. in Dubuque, Iowa. PreTox 2000 is a cementitious paint-like mixture (i.e., treatment layer) designed to be applied to lead-based paint surfaces and allowed to cure and adhere to the paint coating; it then is removed in conjunction with the underlying lead-based paint coating using abrasive blasting or other standard techniques. PreTox 2000 is composed of materials from the compounds of sodium and potassium silicates, sodium and potassium phosphate, and calcium silicate, iron and aluminum sulfates, and an alkali metal salt.⁷ It also contains toluene, acetone, and VM&P naphtha as carrier solvents. Typically, PreTox 2000 is designed to be applied to a 10- to 60-mil (wet) thickness depending on substrate and paint condition; the average application is 40-mil (wet) thickness. For this study, the manufacturer's representative used an airless sprayer to apply PreTox 2000 to a surface of 40 mil (wet) thickness.

The manufacturer reports that the PreTox 2000 system stabilizes the lead through two mechanisms. The first mechanism is chemical stabilization through pH adjustment, which instantaneously stabilizes the lead by adjusting the pH range (8.0-11.5) where there is limited leachability for lead. The second is chemical fixation that changes the soluble ionic form of lead to an insoluble metallic form. Test data provided by NexTec, Inc. showed that PreTox 2000 successfully stabilized lead-based paint debris, yielding a leachable lead content of <5 mg/L using both the TCLP and Multiple Extraction Procedure (MEP).

Data Collection Approach

Study Objective 1

The first study objective was to *evaluate the effectiveness of wet abrasive blasting with an abrasive lead-stabilizer additive (Blastox®) and wet abrasive blasting on a lead-stabilizing surface preparation coating (Torbo®) to remove lead-based paint from exterior wood and brick substrates to a lead loading of <1 mg/cm².*

An effective removal technology is one that can render the substrate as “free of lead-based paint,” defined as a lead loading of <1 mg/cm². In addition, the technology must remove the lead-based paint down to the “bare” wood or brick substrate with minimal or no damage to the underlying substrate. Therefore, a measure of effectiveness must include an assessment of lead removal and abated surface condition. Both of these measures were included to achieve this objective.

One difficulty in comparing the effectiveness of these technologies under real world conditions was that they could not each be applied to the same surface area. Thus, a surface cannot receive a lead-based paint abatement treatment more than once. Under ideal conditions, comparisons of different technologies would best be conducted on the same surfaces. Since abatement can only be done once, however, different surfaces were selected for removal by each technology. The approach for this study was to minimize the potential differences between these surfaces selected for removal by each technology. To minimize these potential differences, a single expanse of painted brick wall was selected with the same painting history and five buildings (two houses and three storage sheds) on the same property with wood siding having similar architectural characteristics and painting histories.

The study approach to achieve Study Objective 1 included the following:

Lead-based paint removal effectiveness was evaluated by measuring the lead loading before and after application of each technology using multiple lead in paint measurements on the substrates (wood or brick) with an X-ray fluorescence (XRF) spectrum analyzer.

The surface condition was assessed by observing the physical appearance of the abated surfaces. A set of standardized terminology (such as lifted or feathered wood grain or pitted wood surface; spalled brick; or dislodged mortar from joints) was used for assessing the condition of the surfaces.

The effects of changing operational parameters were minimized by attempting to hold operational parameters constant between the different experimental replicates for each technology. In addition, the abrasive/Blastox® blend was premixed by the supplier of the abrasives; the PreTox 2000 surface coating preparation was applied by the same manufacturer’s representative; and the same two Torbo® employees (operator and helper) conducted the wet abrasive blasting.

Study Objective 2

The second study objective was to *evaluate the effectiveness of the abrasive lead-stabilizer additive (Blastox®) and the surface preparation coating (PreTox 2000) to stabilize the lead in paint abrasive media waste to below the RCRA regulatory threshold of 5 mg/L in leachate.*

The study approach to achieve Study Objective 2 included the following:

The effectiveness of Blastox® and PreTox 2000 to stabilize the lead in residual paint abrasive media waste was evaluated by collecting samples of abrasive media debris after each technology. The leachable lead content of the waste was determined by TCLP.³

Study Objective 3

The third study objective was to *evaluate the potential for each technology combination (e.g., Torbo® with Blastox®) to generate airborne lead particulate above the OSHA Permissible Exposure Limit (PEL) of 50 µg/m³, 8-hour time weighted average (TWA).*

The study approach to achieve Study Objective 3 included the following:

The assessment of airborne lead particulate generated within the breathing zone of both the technology operator and a helper was performed by collecting personal air samples from the workers during application of each technology combination. The samples were collected and analyzed in accordance with NIOSH Method 7300.

Study Objective 4

The fourth study objective was to *develop comparative estimates of the cost of paint removal and disposal using the two technology combinations.*

The study approach to achieve Study Objective 4 included the following:

The cost estimates that were developed consisted of five components: (1) direct labor cost of lead-based paint abatement; (2) indirect labor cost of lead-based paint abatement (i.e., equipment related to the technology and associated materials, consumables, and utilities); (3) indirect materials cost (i.e., polyethylene sheeting, tape, and materials to construct each work area containment, disposable protective clothing, respiratory protection, and associated support materials); (4) environmental testing for worker safety and waste characterization; and (5) transportation and disposal of waste. The estimated costs are reported for each technology combination and each substrate (wood and masonry) on a per-square-foot-basis.

Preparation of Worker Safety Plans

Prior to commencement of the work, the following documents were submitted for approval by the USACERL Contracting Officer's Representative:

- Hazard Communication Program
- Lead Paint Removal/Abatement Plan
- Respirator Protection Program
- Waste Collection and Disposal Plan
- Worker Protection Plan

Approval was granted on all of these referenced documents prior to the commencement of the technology demonstration. All work was performed in accordance with guidelines contained in these documents.

Site Preparation

The potential environmental hazards from removal of lead-based paint coatings are reduced by minimizing or eliminating the airborne particulate, and by containing and collecting the debris. Hence, the purpose of containment is to prevent or minimize the debris generated during removal of the lead-based paint coating from the substrate from entering the environment (air, soil, or water) and to facilitate the controlled collection of the debris for disposal. The level and type of containment needed is dependent on various considerations such as size, elevation, and location of the structure, and the surface preparation (i.e., paint removal) method used.

Wood -- The initial containment that was constructed for removal of the lead-based paint coating from the wood siding was consistent with an SSPC-Guide 6 Class 2A design⁸ -- i.e., air impenetrable walls and ceiling, fully sealed joints, partially sealed entryway, forced airflow mechanical ventilation, and water impermeable floors. Because of the lack of visibility inside the containment due to the high relative humidity levels generated during wet abrasive blasting, however, the containment was reduced to water-impermeable ground cover consisting of 10-mil nylon-reinforced flame-resistant polyethylene sheeting. (A limited evaluation of the Torbo[®] wet abrasive blasting system by the Department of the Navy under open blasting conditions showed that the fugitive airborne lead-particulate emissions were consistently below the OSHA PEL.) The polyethylene sheeting was fastened to the base of the building to prevent further contamination of the soil. The outer edge of the polyethylene was weighted. The spent abrasive and paint debris was removed from the ground cover using brooms and shovels. The materials were placed in 55-gallon open-top DOT-approved drums.

Brick -- The containment for the removal of the lead-based paint coating from the brick consisted of an SSPC-Guide 6 Type B2 air penetrable woven polypropylene opacity screen (85% opacity) weighing 0.75 oz/ft². The air was able to pass through the containment material. The screen (35-ft by 50-ft) was draped over the side of the

building at each of the test areas. The perimeter of the screen was anchored to the roof of the building using 50-pound bags of sand. The ground was covered with water-impermeable ground cover consisting of 10-mil nylon-reinforced flame-resistant polyethylene sheeting. The polyethylene sheeting was fastened to the base of the building to prevent further contamination of the soil. The outer edge of the polyethylene was weighted with sandbags. The spent abrasive and paint debris was removed from the ground cover using brooms and shovels. The materials were placed in 55-gallon open-top DOT-approved drums.

Sampling and Analytical Methods

Thickness of Dry Paint Film

Locations selected to measure the paint film thickness were representative of the paint over the entire area of the building wall to be abated. Because of the relatively large surface areas (average of 495 ft² per test panel), five measurements of the paint film thickness were made for each of the 12 test panels, yielding a total of 60 measurements. The thickness measurements were made at the approximate center point of each equally dimensioned grid square of a six-part grid system created over each test panel.

The measurement of dry film thickness of the paint was made using ASTM Method D 4138-88.⁹ This in-field method measures the dry film thickness of coating films by microscopical observation of precision-cut angular grooves in the coating film. The range of thickness measurement is 0 to 50 mils (0 to 1.3 mm).

Lead in Dry Paint Film

Lead in paint measurements (XRF and ICP-AES) were made before paint removal to establish the lead loading on the test panel. The measurements were made at approximately the same five locations as the paint film thickness measurements. The measurements were made in accordance with Chapter 7 "*Lead-Based Paint Inspection*" (1997 Revision) of the HUD Guidelines.¹⁰

XRF Measurements

A NITON XRF Spectrum Analyzer (Model 703-A) running software Version 5.1 was used to determine the lead loading on the brick and wood substrates. The instrument was operated in the variable-time paint test mode "*K & L + Spectra*" using the "*Combined Lead Reading*" with the instrument display of a 95% confident (2-sigma) positive or negative determination versus the threshold-level (1 mg/cm²) as the stopping point of the measurement. There is no inconclusive classification when using the threshold for this instrument running software version 5.1.¹¹ Results are classified as positive (i.e., ≥ 1.0 mg/cm²), if greater than or equal to the threshold, or negative (i.e., < 1.0 mg/cm²) if less than the threshold. The instrument reads until a 95% confident reading of "Positive" or "Negative" versus the threshold (1 mg/cm²) is achieved.

The Depth Index displayed by the instrument was also recorded with each measurement. The Depth Index is a numerical indication of the amount of non-lead paint covering the lead detected by the instrument. A Depth Index less than 1.5 indicates lead very near the surface layer of paint. A Depth Index between 1.5 and 4.0 indicates moderately covered lead. A Depth Index greater than 4 indicates deeply buried lead.

In addition to the manufacturer's recommended warmup and quality control procedures, the XRF instrument operator performed the calibration check readings in accordance with the HUD Guidelines.¹⁰ The calibration checks were taken using the Red (1.02 mg/cm²) National Institute of Standards and Technology (NIST) Standard Reference Material (SRM No. 2579) paint film. In all cases, the instrument displayed a value between the calibration check limits (0.9 to 1.2 mg/cm²) specified in the Performance Characteristic Sheet¹¹ and indicated *Surface Lead*. Because all of the lead loadings measured in the paint film before paint removal exceed the calibration standard, the corresponding measurements should be interpreted as approximate or minimum values.

In order to minimize the contribution of variability originating from the XRF instrument and operator during the measurement process, the same XRF instrument and operator were used for all XRF measurements.

Paint Chip Sampling

A paint chip sample for ICP-AES analysis was obtained at approximately the same location as three of the five XRF measurements. Each sample was obtained from a 1¼-inch by 1¼-inch (approximately 3.17-cm by 3.17-cm) square area. The outline of the sample area was marked with an indelible ink pen. One edge of a 5-inch by 7-inch aluminum tray was taped immediately below the sample area and formed to accommodate complete collection of the sample.

Ideally, the goal was to remove all layers of paint equally, but none of the substrate. However, inclusion of small amounts of substrate material in the paint sample would result in minimal error because the primary unit of measure is mass to area (mg/cm²). That is, the entire sample was extracted by the laboratory, and mass of lead present was divided by the area of sample. A new 1¼-inch-wide wood chisel was used to remove the paint film sample from the wood siding. The sample was removed by shaving the paint film surface in a direction parallel to the grain of the wood. To facilitate collection of the paint film sample from the brick, a heat gun was used to soften the paint before removal to minimize the amount of substrate in the sample. The sample area was heated until it became soft and supple. The paint was scraped off the substrate with a clean 1¼-inch-wide metal paint scraper. All paint was removed from wood and brick to bare substrate. The exact dimensions (to the nearest millimeter) of the sample collection area were recorded. The paint sample was transferred from the aluminum tray into a labeled centrifuge tube with screw cap for shipment to the

laboratory. The hard-shelled container was used to facilitate analysis of the entire sample.

The samples were prepared for analysis in accordance with EPA SW-846 Method 3050 and analyzed by ICP-AES in accordance with EPA SW-846 Method 6010. The analytical limit of detection was reported as 5 µg/sample.

Lead on Bare Substrate

Lead on bare substrate measurements (XRF and ICP-AES) were made after paint removal to establish the residual lead loading in the test area. The six wood siding test areas and the six brick wall test areas were each equally dimensioned into 25 areas (i.e., grid squares). The measurements were made at the approximate center point of each grid square. An XRF measurement was made in each of the 25 grid squares. A bare substrate sample for ICP-AES analysis was collected from five of the 25 squares; the test locations were randomly selected.

XRF Measurements on Bare Substrate

A Niton XRF Spectrum Analyzer (Model 703-A) was used to determine the lead loading on the substrate after paint removal.

Bare Substrate Chip

Bare substrate chip samples for ICP-AES analysis were collected to verify the lead loading on the test area determined by the XRF Spectrum Analyzer. The samples were obtained from a 1¼-inch by 1¼-inch (approximately 3.17 cm by 3.17 cm) square area. The outline of the sample area was marked with an indelible ink pen. One edge of an aluminum tray was taped immediately below the sample area and formed to accommodate complete collection of the sample.

A sharp 1¼-inch-wide wood chisel and hammer were used to remove the sample of wood substrate. The sample was removed by shaving the wood surface in a direction parallel to the grain of the wood. A new 1¼-inch brick chisel and hammer were used to scrape/chip the brick surface to obtain the substrate sample. The depth of each sample was approximately ≤ 2 millimeters. The exact dimensions (to the nearest millimeter) of the sample collection area were recorded. The substrate sample was then transferred from the aluminum collection tray into a labeled centrifuge tube with screw cap for shipment to the laboratory. The hard-shelled container was used to facilitate analysis of the entire sample.

The samples were prepared for analysis in accordance with EPA SW-846 Method 3050 and analyzed by ICP-AES in accordance with EPA SW-846 Method 6010. The analytical limit of detection was reported as 5 µg/sample.

Lead in Airborne Particulate

Personal Breathing Zone Samples

Personal breathing zone samples were collected on the technology operator and helper during each technology demonstration, i.e., each worker wore a personal sampling pump with the filter assembly positioned in the workers' breathing zone area. The sampling assembly was worn by each worker for the duration of the technology demonstration. The samples were collected on closed-face, 37-mm-diameter, 0.8- μ m pore size mixed-cellulose-ester (MCE) membrane filters contained in a three-piece cassette. The filter assembly was attached to a constant-flow, battery-powered vacuum pump operating at a flow rate of approximately 2 liters per minute. The sampling pumps were calibrated with a precision rotameter both immediately before and after sampling. The precision rotameter is a secondary standard, and thus was calibrated with a primary airflow standard (a bubble tube) before, at the midpoint, and after each field demonstration (i.e., wood and brick substrates) study.

The samples were collected and prepared for analysis by ICP-AES in accordance with NIOSH Method 7300. The analytical limit of detection was reported as 0.2 μ g/sample.

Area Air Samples

During each technology demonstration, area air samples were collected to determine the extent of lead-particulate emissions from the site. The samples were collected during the same period as the personal breathing zone samples. The samples were collected on closed-face, 37-mm-diameter, 0.8- μ m pore size MCE membrane filters contained in a three-piece cassette positioned on tripods at a height of 4 to 5 feet. The filter assembly was attached to an electric-powered vacuum pump operating at a flow rate of approximately 5 liters per minute. The sampling pumps were calibrated as described for the personal breathing zone samples.

The samples were collected and prepared for analysis by ICP-AES in accordance with NIOSH Method 7300. The analytical limit of detection was reported as 0.2 μ g/sample.

Lead Particulate Aerodynamic Particle Size Distribution

An eight-stage Marple Personal Cascade Impactor (Model 298) was used to determine the aerodynamic particle size distribution of the lead particulate generated by the technology. The cascade impactor physically separates particles by size. Table 4 presents the experimentally determined cut-points at the design flow rate of 2 liters/min (Lpm).¹² The collection substrates for Stages 1 through 8 consisted of 34-mm-diameter slotted-mylar substrates. The backup filter consisted of a 34-mm-diameter, 5- μ m polyvinyl chloride filter.

Table 4. Cascade Impactor Model 298 Cut-Points at 2 Lpm

Impactor Stage No.	Cut-Point ^a D _p (μ m)
1	21
2	15
3	10
4	6.0
5	3.5
6	2.0
7	0.9
8	0.5
Backup Filter	0.00

^a Aerodynamic equivalent particle-size diameter for spherical particles of unit mass density in air at 25° C and 1 atm.

The personal sampler was worn by the technology operator for the duration of the technology demonstration, i.e., during the period of paint removal. The sampler was attached to a constant-flow, battery-powered vacuum pump operating at a flowrate of 2 liters per minute. The sampling pumps were calibrated as described for the personal breathing zone samples.

The samples were collected and prepared for analysis by ICP-AES in accordance with NIOSH Method 7300. The analytical limit of detection was reported as 0.2 μ g/sample.

Characterization of Abrasive Media Paint Debris

Representative samples of the abrasive media paint debris (spent abrasive, stabilization product, paint chips/particles) were collected to determine whether the material generated from a technology combination was a RCRA (40 CFR Part 261)

hazardous waste based on the Toxicity Characteristic Leaching Procedure (TCLP). The TCLP is designed to simulate the leaching a waste will undergo in a sanitary landfill. If the leachable lead concentration is equal to or greater than 5 mg/L, the material is a hazardous waste. The samples were extracted in accordance with EPA SW-846 Method 1311, digested in accordance with EPA SW-846 Method 3015, and analyzed in accordance with EPA SW-846 Method 6010.

Wood Substrate

Initially, six and nine representative samples were obtained from the abrasive media paint debris generated from the Torbo®-Blastox® and Torbo®-PreTox 2000 technology combination demonstrations, respectively. That is, two and three samples, respectively, were collected during each of the three replicate demonstrations. Each of these samples consisted of four subsamples that represented a “W” pattern of the abrasive media paint debris that had deposited on the ground cover around the structure.

Re-sampling of Debris from Wood Substrates

Due to a concern that this sampling strategy may not have yielded representative samples of the debris, the material which was subsequently deposited in 55-gallon drums for disposal was re-sampled. The re-sampling involved removing a 5-gallon container of the Torbo®-Blastox® generated debris from each of four 55-gallon drums; re-sampling was done in the same manner for the Torbo®-PreTox 2000 generated debris. The material from one of the 5-gallon containers was deposited on a hard-flat surface and thoroughly mixed using a shovel. The pile was then divided into four quarters with a shovel. A subsample was then collected from each quarter and combined as a single sample. This procedure was repeated for each 5-gallon container, yielding a total of four samples for each technology combination.

In addition to the re-sampling of the debris, three 5-gallon containers were obtained from the Torbo®-Blastox® generated debris and three from the Torbo®-PreTox 2000 generated debris and then treated with additional amounts of Blastox® or PreTox 2000. The debris was treated with additional amounts of the stabilization products to achieve the optimal blend ratio or mil application thickness, respectively. Additional amounts of dry Blastox® were added to achieve a blend ratio of 30 percent. Additional amounts of dry PreTox 2000 were added to simulate a 60 wet mil application thickness. Retrospectively, these turned out to be the formulations that the respective manufacturers should have used for the demonstration involving the wood substrates.

Representatives from both TDJ Group, Inc. (Blastox®) and NexTex, Inc. (PreTox 2000) participated in selection of the debris for re-testing, mixing of the debris with and without the additional amounts of the stabilization products, and sampling of the debris.

Brick Substrate

Six representative samples were obtained of the abrasive media paint debris generated from the Torbo®-Blastox® technology combination demonstrations, and six

were obtained from the Torbo[®]-PreTox 2000 technology combination demonstrations. Prior to collecting the samples, the resultant abrasive media paint debris that had deposited on the ground cover was culled into a large pile. The pile was thoroughly mixed and divided into four quarters with shovel. A subsample was then collected from each quarter and combined as a single sample. This procedure was repeated for a second sample.

Statistical Methods

All comparisons of two sample means were made using a standard two-sample t-test. If the distributional assumption of normality was not reasonable, then the corresponding nonparametric distribution-free method was used (i.e., Wilcoxon Rank Sum Test). All one-sample comparisons to a regulatory action level (1 mg/cm²) were made using a standard one-tailed t-test. Again, if the distributional assumption of normality was not reasonable, then the corresponding nonparametric method was used (i.e., Signed Rank Test). All of these statistical comparisons were made at the 0.05 level of significance.

The upper limit of the 80 percent confidence interval for the mean concentration of leachable lead in the abrasive media paint debris was calculated to determine if the material was a RCRA hazardous waste.¹³ If the mean concentration of leachable lead plus the 80 percent confidence interval is greater than the regulatory threshold (5 mg/L), the material was considered to be a hazardous waste.

Calculation of 8-hour Time-Weighted Average

The personal breathing zone concentrations of airborne lead were converted to an 8-hour time-weighted average (8-hr TWA) exposure concentration using the following formula:

$$E = (C_a T_a + C_b T_b + \dots + C_n T_n) / 8 \text{ hours}$$

where: **E** is the equivalent exposure for the working shift
C is the concentration (µg/m³) during any period of time T
T is the duration (hours) of the exposure at concentration C.

The 8-hr TWA concentrations associated with the measured airborne levels of lead were calculated assuming zero exposure beyond that which was measured during technology application. That is, the 8-hr TWAs were calculated by multiplying the sample duration (hours) by the measured concentration of lead (µg/m³) and dividing the product by 8 hours. It should be noted that this approach yielded 8-hr TWA exposure concentrations that most likely would be lower than the exposure measured for a worker using the technology during an actual abatement project due to the longer exposure period.